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CONTENTS

	PAGE
Ploughing Alternatives	215
Review: Merrilleana	216
Witches' Broom Disease Investigations	217
Termites in Trinidad and Tobago....	221
Yields of Sugar-Cane Trash	224
Soil Depletion Plots	225
The Relative Yields of Bananas and Potatoes	226
The Moon and Plant Growth	228
Chemical Notes	230

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PLOUGHING ALTERNATIVES*

New methods of cultivation are displacing the plough in certain parts of the world where inversion of the soil has proved detrimental. While the complete replacement of the plough by these new methods has been advocated by some writers, the exponents of ploughing are disagreeing on the advantages or disadvantages of deep as compared with shallow ploughing. Whereas with the surface-cultivation technique the soil is not inverted at all, shallow ploughing turns over the surface layer, and in deep ploughing the subsoil is incorporated in the top layer. Thus these different points of view may be regarded as part of the same problem of the effect of inversion of the soil. In a recent discussion (1) on cultivations that centered round this problem of deep ploughing, T. A. Wedderspoon supported the deep-ploughing method and contended that it brings the maximum volume of soil into production, thus creating a deeper root bed; the depth of ploughing depends on the depth of live soil available and on the crop to be grown. Even the enthusiasts agree that deep ploughing cannot be done indiscriminately. A system should be worked out whereby the depth of ploughing is increased gradually, say, one inch a year. Sometimes it may be necessary to subsoil at least a year before incorporating the subsoil in the cultivated layer. E. W. Russell expressed the opinion that deep cultivation is the obvious means of improving the drainage of heavy land, particularly if it has a plough or tractor-wheel pan causing serious subsoil compaction; but the main advantage of deep ploughing over shallow ploughing is its greatest efficiency in controlling weeds. Farm crops, when young, are sensitive to weed competition, but tolerant to a wide range of soil tilths. This is the conclusion drawn from ploughing and cultivation experiments at Rothamsted, and also reached by other research workers who have made similar experiments. Good ploughing is therefore ploughing that completely buries weeds, and deep ploughing is, in general, of more value than shallow ploughing for this purpose. Under the climatic conditions prevailing in Britain the great advantage of the mouldboard plough is that by burying weeds it kills them in both wet and dry weather while discs only kill weeds in dry weather. Another advantage of deep ploughing is that it can be used to incorporate fertilizers in the subsoil and there is evidence to show that this will help crops to withstand summer droughts.

* Reprinted from *Soils and Fertilizers*, 9, 161-162, 1946. See also *Trop. Agriculture, Trin.*, 21, 141-143, 1944.

In the United States the success of the sub-surface tillage or stubble-mulch technique used in the Great Plains and the Missouri system of small grains—lespedeza which is also a "trashy" system of farming, and the publication of "Plowman's Folly" by E. H. Faulkner have brought the whole question of the status of the plough to the fore. The stubble-mulch technique (2) has been devised to preserve the soil from blowing when the land is not carrying a well established crop. It is adapted to areas of limited rainfall and has been successful in protecting the soil from wind erosion. Faulkner, who roundly condemns the plough and all its works on the grounds that "no one has ever advanced a scientific reason for ploughing" and says that ploughing is harmful and unnecessary, proposes to replace the mouldboard plough with a disc harrow irrespective of climatic, soil and other conditions and thus to extend a variant of stubble-mulch farming to humid areas. Since 1939 the Iowa Experiment Station has been studying different methods of preparing the land and their effect on the yield of maize, the cost of operation and the loss of soil and water (3). The plough is being compared with disc, lister and sub-surface cultivator in the preparation of a seedbed for maize under the conditions of the Corn Belt. It was found that weed control was more of a problem on sub-surface tilled than on ploughed land, that in unfertilized fields maize yields were 8 to 10 bushels per acre higher on ploughed lands than on fields cultivated by other methods, while on fertilized fields listed maize outyielded that on ploughed land by 1.3 bushels per acre. Yields were reduced when seed beds had been prepared by discing or sub-surface tillage. In July the soils of the ploughed plots contained 12 lb. of available nitrogen per acre, while only 3 lb. were found in the sub-surface tilled and disced plots. For growing the maize crop listing used less labour and power than any other method, and erosion control was more effective from listing on the contour than from ploughing.

It seems that the choice between traditional ploughing methods and stubble mulching will in future be dictated by climatic and soil conditions and the kinds of crop grown. The plough is an invention of temperate climates and the early settlers who brought it to the New World from Europe failed to realize the significance from the cultivation standpoint of the different soil and climatic conditions, especially the importance of the transition from regions of regular rainfall coming in small showers to regions of limited rainfall with heavy downpours. In tropical and sub-tropical countries ploughing may adversely affect the properties of the soil. The use of the disc harrow instead of the plough may be necessary where the soil structure is poor, and, even where it is good, disc harrowing may be advisable to maintain the soil in a crumbly condition.

In East Africa alone, the conditions of soil and climate vary so much that each set of conditions needs a special choice of cultivation methods (4). When the farmer ceases to be guided by tradition and starts considering his land before deciding on a suitable cultivation technique, it is likely that mouldboard ploughing will continue to be an essential operation where the conditions are favourable, and will be replaced by stubble mulching or other forms of surface cultivation in regions where the conditions are unsuited to ploughing.

References

(1) Wedderspoon, T. A. and Russell, E. W. Soil Cultivation. *Proc. Instn. Brit. Agric. Engnrs.* 3, 1945 (94-111).

(2) Stubble-mulching and sub-surface tillage. *Soils and Fertilizers* 7, 1944 (57-58).

(3) Norton, R.A., Browning, G.M., Bower, C.A., *et al.* Plows testify again. *Farm Sci. Reptr.* 6, No. 2, 1945 (3-6).

(4) Ploughman's query. *E. Afric. Agric. J.* 10, 1945 (129-130).

REVIEW

Merrilleana

Merrilleana. A Selection from the General Writings of Elmer Drew Merrill, ScD., Ll.D. Pub. Autumn, 1946, by the *Chronica Botanica Co.*, Waltham, Mass, U.S.A. Vol. 10, number 3/4, pp. 127-394, with 23 illustrations, ed. Franz Verdoorn. Price U.S. $4.00.

In the course of a long and distinguished career in both tropical and temperate botany Professor Merrill has covered a wide field of botanical enquiry. The present work celebrates his seventieth birthday and consists of reprints (complete or in excerpt) of some of his more general papers published between 1907 and 1946, purely taxonomic work being, of course, excluded. The topics treated are various, ranging through an account of the ascent of Mt. Halcon in the Philippines; historical and nomenclatorial aspects of the work of certain early botanists (e.g., Rumphius, Loureiro, de Beauvois, Rafinesque, Bartram); phytogeography of the Malayan region (Borneo, Formosa, the Philippines etc.); ethnographical aspects of the botany of cultivated plants and weeds with especial reference to the place of origin of the important tropical crops and to the time and nature of their trans-Pacific distribution; and various notes on herbarium technique, etc.

The viewpoint throughout is, of course, that of the systematist with a great field experience and the whole work makes the most interesting reading. One is impressed by Professor Merrill's breadth of knowledge and capacity for the assimilation of historical and ethnographical data into botanical studies, especially when one remembers that the papers reprinted here form but a part of a far greater bulk of work of a more purely technical nature.

The short papers on herbarium and library technique (VI, IX, XIII, XVI, XVII) could well have been omitted; though perfectly satisfactory in themselves, they add nothing to an otherwise notable volume.

The reviewer found no typographical errors and the printing and layout of the whole work is excellent. N.W.S.

WITCHES' BROOM DISEASE INVESTIGATIONS

XII. Further studies on the infection of cacao pods by *Marasmius perniciosus* Stahel

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1. *Introduction*

Experiments involving the artificial inoculation of cacao pods with *Marasmius perniciosus* Stahel, carried out by Stahel (1919) in Suriname and by Baker and McKee (1943) in Trinidad, elucidated certain features in the infection of young fruits by this fungus. The various manifestations of the disease as it affects the pods were to a great extent explained, the influence of their state of development at the initiation of infection being clearly shown. There were, nevertheless, a few discrepancies between these Suriname and Trinidad observations, and further pod inoculation studies have been carried out by the writer in Trinidad, during the latter part of the wet season, in three successive years, to amplify earlier work. These experiments, of which the results are presented, indicate that there is little difference in the behaviour of the fungus under Suriname and Trinidad conditions as far as pod infection is concerned.

The method of obtaining spores for the experiments, and the inoculation technique employed, were substantially the same as in previous studies at the Imperial College of Tropical Agriculture (Baker & Crowdy, 1943; Baker & McKee, 1943). Dry vegetative brooms were placed on trays, which drained freely, in large glass-sided chambers, and sprayed with water for half an hour once or twice daily. Whenever the brooms became too damp for prolific sporophore production, the doors of the chambers were left open in between waterings. Old brooms, bearing sporophores when collected, were found to go on producing them in the chambers, almost without interruption. To obtain spores, freshly cut sporophores were arranged on slides in Petri dishes, within which the atmosphere was kept humid with a pad of moist cotton wool, and these dishes were placed in a cool spot. When suitable spore deposits were obtained, they were removed and made into a spore suspension with tap water, this being sprayed on to the pods with an atomiser.

Baker & Crowdy (1943) have shown that sporophores do not begin to deposit spores to any marked extent until the temperature has fallen to 80°F., so that although deposition usually starts around 6.00 p.m., an adequate supply of spores is not normally available until 10.00 p.m. at the earliest. Since their germination may start within two hours of deposition and be almost completed four hours later, spores must be used the same night. Furthermore, for penetration, the germinating spore needs a period of some hours in an atmosphere of complete or almost complete saturation; such conditions do not normally occur in Trinidad during the daytime. Consequently, all inoculation experiments had to be carried out between 10.00 p.m. and 12.00 p.m.

2. *Types of pod infection*

Descriptions of most of the types of pod symptoms caused by *Marasmius perniciosus* have been given by earlier workers (Stahel, 1919; Baker & McKee, 1943; Baker & Crowdy, 1944); but it is considered that they may with advantage be discussed again, in the light of continued observations on naturally and artificially infected pods.

(a) Indirectly infected pods (Fig. 1B) are sometimes produced on diseased flower cushions, from which the infection spreads; with some cacao varieties they are formed rather commonly. The invasion of these fruits by the fungus is systemic, they show no trace of developing ovules, and according to Posnette (unpublished) are parthenocarpic. They usually become "strawberry-shaped" due to hypertrophy of the cortex, while retaining the ridges characteristic of normal pods. Although generally smaller, indirectly infected pods may reach 6 cms. in length on certain cacao varieties. Ultimately, they turn dark brown and dry out, often becoming very hard; in this condition *Marasmius* mycelium can often be found in the hollow centre of the fruit.

All the remaining types of pod symptoms, described below, are produced by penetration of the young fruits by the germ-tubes of one or more germinating spores, which, according to Stahel (1919), gain entry through the stomata.

(b) In fruits becoming infected when of the order of 1 cm. in length, the invading mycelium spreads throughout the tissues and the pods become "carrot-shaped", having thickened pedicels and broad shoulders and tapering to a blunt tip (Fig. IIB). They continue to grow for some time after infection and, for some cacao varieties, may at times reach a length of 12-15 cms. before becoming necrotic and drying out. Like the indirectly infected pods, they often become very hard. The beans in these systemically infected pods are small, and at first contain a clear liquid; on drying out, characteristic *Marasmius* mycelium can often be seen in and around them.

(c) Distorted pods may be formed, in which hypertrophy of the shell occurs in the invaded areas, giving rise to an asymmetrical shape (Fig. IIIB). These develop following the infection of fruits somewhat larger than those which become systemically infected (compare Figs. IIA & IIIA). For large-fruited types of cacao, like the I.C.S. 1 clonal selection, swellings may develop on pods up to 5 cms. long at the time of infection; for smaller-fruited types the limiting length for asymmetry to develop is about 3 cms., but the fruits are probably of comparable age. Swollen pods do not ripen normally, the infected areas becoming hard, and turning dark brown or black in colour before full size has been attained; their beans are completely destroyed.

(d) Pods becoming infected when rather larger (Fig. IVA) than those considered above show no visible sign of infection until ripening, when the shell becomes very hard and woody, and the infected area (or areas) turns dark brown or black (Fig. IVB). Because of their hardness, such fruits have been termed indurated or stone pods. They show no departure from the normal shape. Damage to the beans is usually widespread; generally much more so than the extent of the shell necrosis would suggest (Fig. IVC). The mucilage tissues are affected, so that the beans do not separate as in healthy ripe pods. If a young pod of a small-fruited type of cacao becomes infected at one point only, when longer than about 5 cms., it is likely that some of the beans will remain unspoiled; for larger-fruited types this will generally only be so if infection occurs after the pod has reached 7 or 8 cms. An infection below these limits, however, may damage only a proportion of the beans, while the invasion of larger fruits at several points may spoil all of them. If a diseased pod with some beans unharmed is not picked promptly on ripening, these also are soon destroyed.

(e) Damage to cacao pods by the witches' broom fungus may sometimes be restricted to the rind. A small area of necrotic speckling in the outer shell, as the pod approaches maturity, gives rise to a small black spot. There is more extensive necrosis of the soft inner layer of the shell (Fig. VB), and such a rind infection may sometimes be accompanied by a slight browning of the adjacent beans, though virtually no damage is caused if the pod is harvested promptly on ripening. Occasionally, ripe pods are encountered which have no obvious external symptoms but show browning of the inner layer of the shell and a little bean damage (Fig. VC). In these instances, close inspection generally reveals a slight necrotic speckling of the corresponding area of the outer rind, which cultures have shown to contain the mycelium of the fungus. Inoculation experiments have indicated that these mild pod symptoms, which are comparatively rarely encountered in the field, generally result from the infection of rather larger fruits than those developing the more severe symptoms described above. For a large-fruited cacao, like I.C.S.1, such mild symptoms may follow the infection of pods comparable in size with that depicted in Fig. VA. (N.B. *All the figures are one half natural size*).

(f) When a young witches' broom infected fruit succumbs to "cherelle wilt", the area (or areas) in which the fungus has become established remains alive for a short time after the remainder of the tissue has died. Sections show that in some instances the invaded areas may be white and fully turgid, while the rest of the pod may be largely blackened. These wilting pods quite often show hypertrophy of the cortex in the infected parts, as shown by Fig. VIB; such a young fruit, but for the onset of wilt, doubtless would have developed into a pod similar to that shown in Fig. IIIB. There is no reason to suppose that small witches' broom infected fruits are either more or less likely to be affected by "cherelle wilt" than healthy ones of the same size. This wilting of young pods is a physiological phenomenon, resulting from the setting of more fruits than the cacao tree is able to carry through to maturity (Humphries, 1944).

(g) Other pod-rotting fungi may attack *Marasmius* infected pods, either as secondary or independent primary pathogens. *Colletotrichum* spp., *Botryodiplodia theobromae* and *Phytophthora palmivora* are sometimes found masking the symptoms of *Marasmius* attack. Instead of becoming hard, the shells of pods infected by one or more of the other fungi in addition to witches' broom disease tend to become soft, and blackening of the rind is generally more extensive.

3. *Experimental infection of pods with Marasmius perniciosus*

In Table I are presented the results of the writer's pod inoculation experiments at the Imperial College of Tropical Agriculture. The cacao used in these experiments was of two kinds; fruits of an Amazonian Forastero cacao from Brazil, known as Maranhao, were employed in one series, and those of the Trinitario I.C.S. I clonal selection in the other. The varieties are not comparable with regard to size and shape of pods, the former having a pod normally 10-14 cms. long and with a comparatively large diameter at maturity, and the latter having a pod up to 23 cms. in length. Furthermore, there is no reason to suppose that the pods of these varieties are equally susceptible to the disease, although both have been readily infected artificially. Consequently, the results of inoculation experiments are presented in two groups.

Since most of the fruits used in the experiments of Stahel (1919) and Baker and McKee (1943) were relatively small, it was decided to concentrate on larger pods; at the same time, numerous smaller pods were inoculated for comparison. When possible, trees carrying a range of fruits of all ages were used in the experiments, all those on any one tree normally being inoculated at the same time. A great many of the smaller inoculated pods succumbed to the physiological "cherelle wilt", this being particularly severe on the young I.C.S. 1 trees, which were too small to carry a heavy crop to maturity, although in many instances setting large numbers of young fruits. Pods wilting within three weeks of inoculation are not classified in Table I, but those wilting after this period are recorded, since it is then possible to

Explanation of diagrams (all ½ natural size). Fig. I: flower on infected cushion, A, may give rise to indirectly infected pod, B; L.S. of this pod, C, shows systemic necrosis. In Figs. II-VI, A indicates size of fruit at infection. Fig. IIB; L.S. of systemically infected "carrot-shaped" pod. Fig. IIIB: L.S. of distorted pod with hypertrophy and blackening of invaded areas of shell, and complete internal necrosis. Fig. IV: B, indurated pod with two separate infections; T.S., C, shows widespread internal damage. Fig. V: B, a rind infection with no bean damage; C, pod showing minor damage to a few beans and slight speckling of adjacent rind tissues, but no black spot; both result from infection of relatively large pods like A. Fig. VIB: infected fruit which has succumbed to "cherelle wilt."

FIG. I

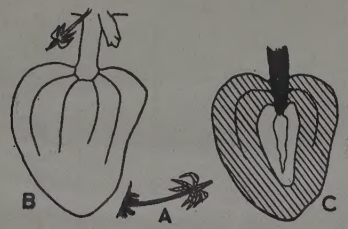

FIG. II

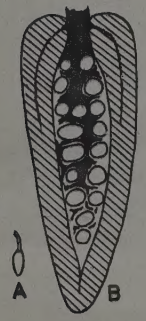

FIG. III

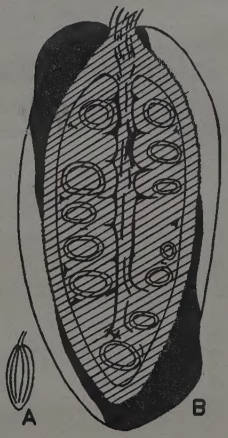

FIG. IV

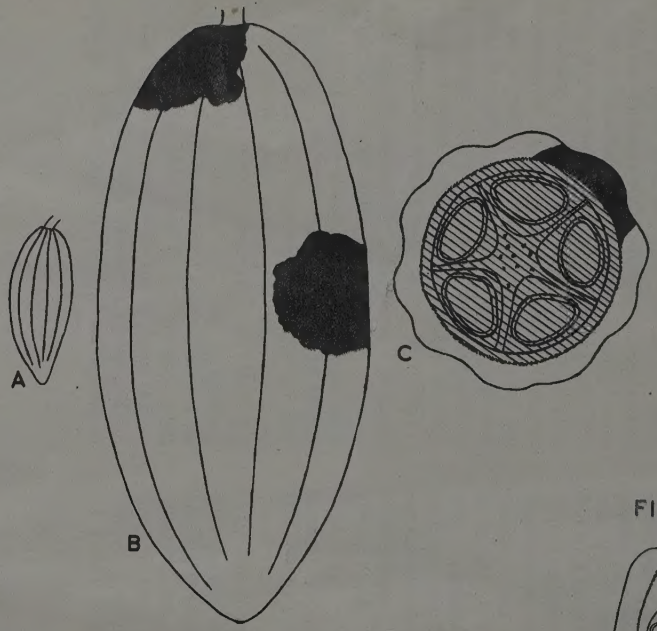

FIG. V

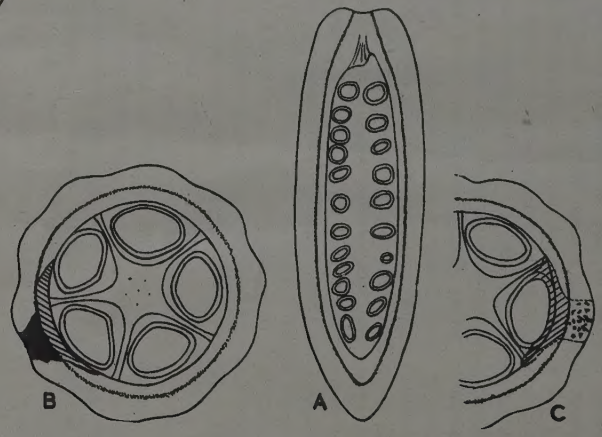

FIG. VI

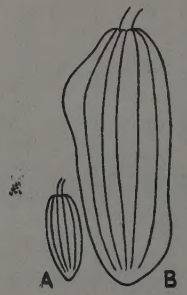

TABLE I

POD INOCULATION EXPERIMENTS

Length of pod in cms. at inoculation	Type of infection produced					Not infected	% success
	A	B	C	D	E		
(a) Trinitario cacao (I.C.S.1)							
Up to 6.9	—	—	1	11	10	18	55
7 „ 8.9	—	—	1	1	—	13	
9 „ 10.9	—	3	3	1	—	18	28
11 „ 13.9	3	2	1	1*	—	10	
14 „ 21.9	—	—	—	—	—	37	0
(b) Brazilian Forastero cacao (Maranhao)							
Up to 6.9	—	1	8	22	2	20	62
7 „ 8.9	2	1	4	—	—	22	24
9 „ 13.9	—	—	—	—	—	103	0

* The total destruction of this pod followed infection at two points.
A = pods showing only rind infection.
B = pods with a few of the beans damaged.
C = with half of the beans damaged.
D = pods with all of the beans damaged.
E = wilting " cherelles " infected by the disease.

diagnose infections of the type described under (f) in the preceding section; the infected wilting " cherelles " are recorded in Column E of Table I, the remainder being included in the " not infected " column. When there was any doubt regarding the infection of a pod, cultures were made from the tissues, *Marasmius perniciosus* mycelium being easily recognisable.

The Table clearly shows a decrease in the severity of pod symptoms with an increase in the size at which the young fruits become infected. The measurement of pod lengths gives a convenient, though approximate, comparison of their ages. Stahel (1919) was able to produce rind infections in Suriname, the largest pod infected in this way being 14 cms. long at infection and reaching 19 cms. at maturity. This is comparable with the I.C.S. 1 fruits of the 11 to 13.9 cm. group on which the writer has produced rind infection; these reached 19-20 cms. at maturity. Baker and McKee (1943) did not succeed in the infection of pods longer than 6.0 cms., except in one instance when a fruit of the 6-6.9 cm. group was infected; no rind infections were obtained. Stahel obtained indurated pods by inoculating fruits up to just under half their length when full grown, the largest being 7.5 cms. The extensive damage which sometimes followed the inoculation of larger pods in Trinidad could generally be attributed to multiple infections. Stahel inoculated only one small area of each pod, but when an atomiser is employed, spores are deposited over most of the pod surface and the likelihood of multiple infections is increased.

Table I also gives an indication of increasing resistance to witches' broom infection by pods of both varieties of cacao as their development proceeds. In each section of the Table, the pods up to 6.9 cms. in length are grouped for the purpose of calculating the percentage success in the inoculations; up to this length there is no indication of changing susceptibility with increasing size, and both varieties appear to be comparably susceptible to artificial infection. Between 7 and 13.9 cms. for I.C.S. 1, and 7 and 8.9 cms. for Maranhao cacao, the susceptibility is markedly less, and above these limits no infection was obtained. A decrease in susceptibility is also shown by a drop in the number of multiple infections which develop; when small fruits were inoculated, four, five or even more distinct infections sometimes manifested themselves in due course.

Cheesman (1927) has shown that increase in the external dimensions of healthy cacao pods ceases 130 to 150 days after fertilisation. Observations on I.C.S. 1 during the present investigation indicate that, under the prevailing conditions, the fruits of this variety normally ripen 175-195 days after fertilisation, 40-45 days of this period being spent in maturation after full size has been attained. The average lengths of time elapsing between inoculation with witches' broom disease and the appearance of necrotic symptoms, for certain types of pod infection on I.C.S.1 cacao, are listed in Table II. A, B and C represent

TABLE II

INOCULATION PERIODS FOR POD INFECTION

Types of pod infection	A	B	C	D1	D2
Mean incubation period (days)	84	83	87	90	89
Normal ripening period (days)	(89)	(97)	(107)	(124)	(147)

the same degrees of pod damage as in Table I; under D1 are listed indurated pods with destruction of all their beans, such as that depicted in Fig. IVB, and D2 represents distorted pods, like Fig. IIIB. The numbers below, in parentheses, represent the average times taken by healthy pods, of sizes equivalent to those of the various infected groups at the time of inoculation, to reach maturity.

It will be seen that necrotic symptoms appear, in each instance, after a comparable period of time. For groups A, B and C the means are calculated from a comparatively small number of pods, while in any category the extreme values may differ by as much as 20 days; consequently, there is no significant difference between the means. Distorted pods become necrotic a considerable length of time before the ripening of corresponding healthy controls, in fact before the normal size has been attained. The onset of necrosis in indurated pods also precedes normal ripening, but by a period less than the 40-45 days normally spent in maturation after maximum size has been reached; consequently, these pods are usually of normal size. Their premature ripening may account for the observed failure of the beans to separate when such pods are opened. There also appears to be a tendency towards premature ripening in pods with a proportion of their beans undamaged (B and C).

4. *Discussion and suggestions for further work*

The observed decrease in severity of pod symptoms with increasing size at infection is a logical phenomenon, needing no further comment. The decreased susceptibility to infection shown by fruits of both varieties studied, on reaching a length of about 7 cms., followed after a further period of development by complete immunity, is an interesting feature. A study of the morphological and physiological changes taking place in young fruits at this stage might indicate the resistance mechanism involved, which in turn might provide a clue to the differences in suseeptibility to pod infection which seem to be exhibited by certain I.C.S. clones (Baker & Dale, 1944). In the latter connection, the carrying out of artificial inoculation experiments on the pods of "resistant" and "susceptible" clones, under identical environmental conditions, would seem to be desirable.

The influence of environmental factors on pod infection also needs thorough investigation; this could best be studied on the same clone, or clones, growing under differing topographical and climatic conditions, but clonal cacao is not yet sufficiently widespread in Trinidad for this purpose.

The major part of the Trinidad cacao crop is picked during the December to March period, and, in those areas where witches' broom disease incidence is high, serious loss of crop is caused during these months, mainly by pod infections of the types represented in Figs. IIIB and IVB. Table II indicates that these infections are initiated during the September to December period, when conditions are often particularly favourable for the production of sporophores of the fungus (Baker and Crowdy, 1943); thus, large numbers of spores are liberated when many young fruits of a susceptible age are on the trees, and climatic conditions are doubtless highly satisfactory for infection. The possibility of controlling witches' broom disease by spraying with a fungicide has been studied by Thorold (unpublished), who found that no benefit resulted. It is felt, however, that in view of the increased price of cacao, and the projected large-scale planting of high yielding clonal material, the possibility of economically protecting pods from infection should be re-examined. It is suggested that in a preliminary experiment the effect of spraying pods up to the limiting size for susceptibility, at weekly intervals during the September to December period, should be tested. By confining attention solely to the small pods, it should be possible to cover a large area fairly quickly, using a simple type of sprayer, and thus increasing the chances of an economic reduction of pod losses. If the results of such an experiment were encouraging, the effect of less frequent sprayings might be investigated.

5. *Summary*

(a) Further pod inoculation experiments with *Marasmius perniciosus* Stahel have been carried out at the Imperial College of Tropical Agriculture, in order to amplify the observations of earlier workers on the infection of cacao fruits by this fungus. It has been shown that there is little difference in the behaviour of the fungus under Suriname and Trinidad conditions as far as pod infection is concerned.

(b) Descriptions are given of the various manifestations of pod infection which may be encountered.

(c) Results of pod inoculations on the Maranhao and I.C.S.1 cacao varieties are presented in tabular form. It has been shown that there is a decrease in the severity of symptoms with an increase in the size at which the young fruits become infected. Pods of I.C.S.1 up to 13.9 cms. and those of Maranhao cacao up to 8.9 cms. were successfully inoculated; some of the larger fruits developed infections confined to the shell, this being the first artificial production of rind infections in Trinidad; others, on ripening, showed only slight damage to a few beans. There was an indication of increased resistance to witches' broom disease, in both varieties, after pods had reached a length of about 7 cms.

(d) The average period of time elapsing between initial infection and the appearance of necrotic symptoms was calculated for each of the larger types of witches' broom pod; these included distorted pods (Fig. IIIB), indurated pods with destruction of all their beans (Fig. IVB), pods with half of their beans damaged, those with only a few beans damaged, and those with infection confined to the rind (Fig. VB). These periods averaged from 80-90 days in each instance, and a comparison with healthy controls, of sizes similar to those of the various infected groups at the time of inoculation, shows that infection tends to produce premature ripening; this is more marked with the seriously damaged pods, which become infected when comparatively small.

(e) Further lines of work on pod infection with witches' broom disease are suggested.

6. *Acknowledgments*

The writer is indebted to Professor R. E. D. Baker for his assistance and interest throughout these investigations, and to Professor E. E. Cheesman for the use of the cacao trees which were employed in the inoculation experiments.

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TERMITES IN TRINIDAD AND TOBAGO, B.W.I.

By

A. M. ADAMSON

(The following note was prepared by the late Professor A. M. Adamson in answer to a questionaire from the Executive Council of the Imperial Agricultural Bureaux (Ed.)

General Observations

This note is based on collections and observations made in the years 1933-39. The writer's survey of the termite fauna of Trinidad approaches completion, probably over 75% of all species having been collected. A general survey of termite damage has been made, sufficient to determine the approximate status of the most destructive species, but an extensive and thorough survey has never been undertaken. A preliminary report on the termite problem in Trinidad, and notes on destructive species in the Lesser Antilles generally, have already been published ("*Tropical Agriculture*", *Trinidad*, 14, pp. 141-9, 1937 and 15, pp. 220-4, 1938). Systematic and biological studies are in progress.

An extensive series of durability trials with local and imported timbers, at four "graveyards" in typical localities, was set up by the Forest Department of Trinidad in 1937. Records of attacks by termites and fungi are being made at intervals of six months, in collaboration with the Departments of Entomology and Mycology of the Imperial College of Tropical Agriculture. The effect of impregnation with creosote is included in these trials. These results have been published in *The Caribbean Forester*, 2, pp. 101-119, 1941.

Apart from the above, little has been done on the termite problem in Trinidad, in spite of the extensive damage. Few if any of the best standard methods of control are practised widely and efficiently, and none has yet been tested adequately. In a large proportion of houses, of rich and poor alike, the only measure taken against termites is the replacement of wood that has been destroyed by them. The greatest immediate need is for education with regard to the extent of damage done and the methods of control most easily applied locally.

According to observations made during brief visits to Tobago, the termite problem there is essentially similar to that in Trinidad.

Attention may be drawn here to the problem of restricting the spread of certain termites in the British West Indian area. For example, the destructive genus *Coptotermes* has been reported very recently in Jamaica (the introduced *C. javanicus* Kemner), Barbados (a species as yet undetermined), and Grenada (*C. testaceus* (L.)). The only other records of this genus in the West Indies are those of *C. testaceus* in Trinidad and Tobago.

I. List of Species

Species attacking human structures are indicated. The others are not known to be of economic importance, but some of them may be destructive, e.g. to humus in soil.

Kalotermitidae

Kalotermes, about 3 spp., some new.
Neotermes, about 3 spp., some new.
Rugitermes, 2 spp.n.
Cryptotermes brevis (Walker)—major pest, buildings and furniture.
„ ? *dudleyi* Banks (tentative determination)
„ about 3 spp.n. and undetermined.
Glyptotermes sp.n. ?
Calcaritermes nigriceps Emerson
„ sp.n.

Rhinotermitidae

Heterotermes tenuis (Hagen) — major pest, ubiquitous.
Coptotermes testaceus (L.) — major pest, but less common than *Heterotermes*.
Rhinotermes longilabius Emerson

Cornitermes (*Labiotermes*) *labralis* Holmgren
Termitidae
Armitermes (*Armitermes*) *holmgreni* Snyder
„ sp.n. ?
Obtusitermes sp.n.
Nasutitermes costalis (Holmgren) — medium pest, old buildings, fences, etc.
„ *ephratae* (Holmgren) — minor pest, cf. *N. costalis*
„ *guayanae* (Holmgren) — minor pest, cf. *N. costalis*
„ *intermedius* Banks.
„ about 3 spp.n. and undetermined.
Subulitermes parvellus (Silvestri)
„ *snyderi* Emerson
„ about 6 spp.n. and undetermined.
Angularitermes sp.— ? nasutissimus Emerson
Anoplotermes brevipilus Emerson
„ *silvestrii* Emerson
„ *banksi* Emerson
„ about 4 spp.n. and undetermined.
Termes (*Mirotermes*) *hispaniolae* (Banks)
Cavitermes tuberosus Emerson
Crepititermes verruculosus Emerson
Neocapritermes angusticeps Emerson
Microcerotermes arboreus Emerson — medium pest, old buildings, fences, etc.
„ sp.n. ?

II. Nature and Extent of Damage

In the absence of extensive surveys, no estimate of annual damage is attempted in the following notes.

(a) *Humus in soil*

Damage to agricultural lands in Trinidad due to consumption of humus by termites has not been noted and is probably not extensive. In most soils liable to deficiency of humus, termites are probably not very abundant, except perhaps in some cacao plantations. In certain soils, especially in natural forests, termites that probably consume humus are very abundant, but here they may play a beneficial role by hastening the disintegration of humus which is always present in sufficient quantity. The writer proposes to study the relations between termites and soil fertility.

(b) *Growing crops*

Termites are not known to attack any growing plants in Trinidad to a serious extent. Minor damage to cane setts by *Heterotermes tenuis* may occasionally occur, and a few cases of damage to transplanted seedlings of ornamental shrubs have been reported to the writer. Some of the Kalotermitidae may penetrate from dead to living wood of trees such as cacao, but apparently with little or no effect on the general health of the tree.

(c) *Forest trees*—see (b).

(d) *Stored timber*

Inspection of stored timber in a few lumber yards and elsewhere has thus far revealed surprisingly little damage. Extensive damage is not likely to occur, except as a result of gross neglect. *Heterotermes tenuis* and *Coptotermes testaceus* are the species most likely to attack stored wood. *Cryptotermes brevis* works too slowly to be a serious menace. *Nasutitermes* spp. and *Microcerotermes arboreus* are capable of attacking lumber in forests or other natural surroundings, but are not likely to occur in a properly maintained lumber yard.

(e) *Telegraph poles and fencing*

It is safe to say that a pole of non-resistant, untreated wood has little chance of withstanding destruction by *Heterotermes tenuis* for more than one or two years, and extensive damage has doubtless occurred. Most telegraph poles are now treated with creosote (see III (d)).

Fences, small bridges and similar wooden structures in contact with the ground are also likely to be destroyed or seriously damaged in less than two years. In addition to *Heterotermes*, species of *Coptotermes*, *Nasutitermes* and *Microcerotermes*, and possibly others, are important agents of decay. Losses are very extensive, though mainly affecting structures erected at small cost.

(f and g) *Buildings*

All buildings, government and private, may be considered together, in the absence of thorough surveys of damage to either class. The amount of damage cannot be estimated accurately, but may be described as very extensive, though proceeding less rapidly than in parts of Africa, for example. Damage by dry-wood termites is much more widespread in buildings than by subterranean species, but the latter are of course much more destructive where they occur.

Cryptotermes brevis (Walker) is the only dry-wood termite of major importance in buildings. Of a few scores of buildings examined, in several parts of Trinidad, over 75% have been found to be infested. It may be inferred that almost all buildings in Trinidad more than a few years old, and articles of furniture in them, are damaged in greater or less degree by this termite.

Heterotermes tenuis (Hagen) is the most destructive subterranean termite in Trinidad, and the most ubiquitous of all species. Of a few dozen buildings examined, in country districts, between 30% and 50% have been found to be attacked. In the city of Port-of-Spain, few observations have been made, but the degree of infestation is probably rather lower than in the country.

Coptotermes testaceus (L.), though more destructive than *Heterotermes* where it occurs, has been found by the writer in only three buildings in Trinidad and one in Tobago. In all cases damage was very extensive and a large part of the woodwork had to be replaced. Probably this species has a localised distribution and in certain parts of Trinidad, where no examinations have

been made, it may be much more destructive than appears at present.

Other termites have rarely been found attacking sound wood in buildings. The following subterranean species, approximately in order of importance, have been found attacking old, neglected or poorly constructed buildings in country districts; in many if not most cases they probably followed attacks by *Heterotermes* or *Cryptotermes, Nasutitermes costalis* and other species, *Microcerotermes arboreus, Termes* (*Mirotermes*) *hispaniolae.*

III. Methods of Protection

(a) *Subterranean termites*

The principal method against subterranean termites in Trinidad is the use of concrete pillars, raising the buildings to heights of one to ten feet from the ground. In a few cases these pillars rest on a concrete foundation covering all the ground under the house, or even to a distance of a few feet around it. In some buildings set on the ground all structures within a few feet of the ground are of concrete. In still fewer the use of wood is avoided except for floors well above the ground.

A "termite-proof metal course over the whole foundations" has not been used in Trinidad, so far as the writer is aware. A "termite shield" of galvanised iron has recently been installed at the top of concrete pillars in a few buildings. Unfortunately no termites had attempted as yet to build covered passages over the shields examined by the writer. He hopes to test the method further, as it might have a wide application here.

The methods in use as mentioned above are only partially effective. Even buildings raised on concrete pillars several feet high are frequently invaded by *Heterotermes tenuis,* which usually builds its covered passages in concealed places. These are often provided by careless construction. In some cases the installation of wooden steps or other wooden structures in contact with the ground provides an easy entry for the termites. If properly constructed and *reasonably cared for,* a building on concrete pillars of more than two feet high should be immune from attack.

Concrete foundations, with and without pillars, prevent invasion to a considerable extent, but by no means completely. Their failure is largely due to cracks, as a result of earth tremors or shifting. (Severe earthquakes are unknown in Trinidad.)

(b) *Dry-wood termites*

Scarcely any means of prevention is employed specifically against dry-wood termites. Such methods as use of resistant and treated wood, screening of houses, etc., reduce the damage done, but are not usually designed primarily to prevent invasion by these termites.

(c) *Stored timber*

Isolation of lumber from the ground, by means of concrete pillars, metal rails, etc., appears to be the only preventive method widely used. So far as observed, it seems to be reasonably effective (see also II (d)).

(d) *Termite-proofing of timber*

Creosote is the preservative most widely used in Trinidad. It is generally applied by surface brushing. It is well known that this superficial treatment does not afford lasting protection to wood in contact with the ground. Other preservatives similarly used are "Atlas" and "Stoprot."

The only adequate tests made are those included in the durability trials of the Forest Department of Trinidad, mentioned above. A large series of timbers, local and imported, were treated with a mixture of equal parts of creosote and diesel oil, by the hot and cold, open tank method. After two years in the ground, none of the treated test pieces has shown any sign of damage from any cause. They have been fully exposed to attack by *Heterotermes tenuis* and *Coptotermes testaceus.*

(e) *Indigenous resistant timbers*

The following local timbers are highly resistant to all termites and are used to a considerable extent: Balata (*Mimusops balata* var. *cruegeri* Pierre), Black Fiddlewood (*Vitex divaricata* Sw.), Cedar (*Cedrela mexicana* Roem.), Guatecare (*Eschweilera subglandulosa* (Steud. Miers) and Yellow Poui (*Tabebuia serratifolia* Nichols).

The durability trials of the Forest Department, already referred to, will soon provide adequate data on the relative susceptibility of all local timbers to attacks by the principal subterranean termite, *Heterotermes tenuis,* as well as to *Coptotermes testaceus.* It is not considered advisable to quote any of the results at the present stage of the experiments.

IV. Repair of Termite Damage

The usual method of repairing termite damage is simply replacement of damaged wood. In a few cases some preventive measures may be adopted (see III (a and b)).

V. Destruction of Nests

No termites in Trinidad construct very large exposed nests. The arboreal termitaria of *Nasutitermes* and *Microcerotermes,* not exceeding a few feet in length, are easily removed and repellents such as creosote are fairly effective in preventing reconstruction of the nest. Arsenical and other poisons, introduced into a hole in the top of the nest, are used to a very limited extent, but with fair success. The subterranean nests of *Heterotermes* and *Coptotermes* are of course difficult to find and their destruction as a means of control is not practicable.

VI. Legislation

No legislation concerning termites appears to exist in Trinidad. There is urgent need for such provisions in building codes, especially since damage could be reduced relatively easily in the case of many types of building used locally.

YIELDS OF SUGAR-CANE TRASH

By L. J. C. EVANS And F. HARDY
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Introductory

Information concerning the relative yields of sugar-cane stems and of tops, leaves and trash, as well as roots, is important in assessing the contribution made by crop residues to the supply of soil organic matter in sugar-cane fields. The contribution made by *cane-roots*, as assessed by the soil-core method of sampling in Trinidad and Barbados, has already been considered in a previous article (1) in which it was shown that the magnitude of this fraction of the total crop residues left by an average crop is comparatively small, namely, approximately 34 cwt. per acre 6 inches of soil, or 0.20 per cent. by weight, although naturally it varies according to type of soil, variety of cane and stage of growth. Furthermore, it was estimated that, when the root residues are changed in the soil to humus, a loss of about 70 per cent. in weight occurs, so that the weight of root humus contributed to the soil is about 10 cwt. per acre 6 inches, or about 0.056 per cent. of the weight of the soil.

With regard to the contribution made by cane-tops (unfolded shoots), green leaves and dry trash, data in the literature are somewhat conflicting. Thus, in his well-known book, *"Cane Sugar"*, Noel Deerr quotes Maxwell's findings in Hawaii, namely, that the dry matter of stalks is 40 per cent. of the whole crop, that of leaves 55, and that of roots 5 per cent. The moisture contents of fresh stalks and green leaves may each be taken as about 75 per cent. by weight, so that the proportion of stalks to leaves will be approximately the same as that of their dry matter contents. Hence a 40-ton crop of fresh stalks will leave behind when stripped and reaped, some 55 tons of green leaves. Assuming further that the moisture content of *dry* leaves (cane-trash) is 35 per cent., then 55 tons of green leaves will be equivalent to 21 tons of dry trash. This result, namely, 21 tons of trash from a 40-ton crop of sugar-cane, seems rather high!

By contrast, H. M. Leake (2) states that cane-trash comprises between 15 and 20 per cent. of the total crop, so that a 40-ton crop of stalks should be accompanied by only 7 to 10 tons of dry cane-trash. Finally, W. C. Stubbs (3) quotes Ross's finding that (in Louisiana), in a total crop of 45 tons per acre, 15 tons consist of tops and leaves and 30 tons consist of stalks. This means that 40 tons of stalks are accompanied by 20 tons of green matter, which is only about one-third of Maxwell's result. Stubbs himself states that, in Louisiana, the proportion of cane-stalks to tops and leaves is about 3 to 1, so that, for a 40-ton crop of stalks, there would be 13 tons of tops and leaves which is considerably less than Ross's result. If we accept Ross's figure of 20 tons of leaf material for a 40-ton crop of cane, and assume a 50 per cent. average moisture content for this material (which comprises in actual fact green tops, mature to senescent green leaves and trash), then the amount of dry trash ultimately left behind on the land after the crop had been reaped would be 10 tons per acre, or one-quarter of the weight of the stalks.

Results obtained at the College Farm

In order to check the data presented above, actual measurements of the relative weights of stalks, tops and green leaves, and dry trash were made at the College Farm in Trinidad during the 1946 crop season. The yields of these fractions of the total crop were weighed for three stages of growth (plants, first ratoons, second ratoons) of several varieties of sugar-cane grown in plots. The results obtained, expressed as tons per acre, are given in Table 1. In order to reduce the weights of tops and green leaves to corresponding weights of air-dry trash, the moisture contents of large representative samples of tops, green leaves and trash were determined in the laboratory. The following results were obtained:—

Tops, 381.6 parts moisture accompany 100 parts of oven-dry matter.
Leaves, 258.4 parts moisture accompany 100 parts of oven-dry matter.
Trash, 54.6 parts moisture accompany 100 parts of oven-dry matter.

The mean for tops and leaves is 320 per cent.; hence, 420 parts of fresh tops and green leaves, assuming that equal proportions of each are produced, would give, on ultimate conversion in the field, about 155 parts of dry trash. Thus one part by weight of green tops and leaves is equivalent to 0.37 parts of trash. The conversion factor, 0.37, has been used in the appended table for estimating the total yield of leafy matter, reckoned as trash, which would ultimately be produced were the stems alone reaped and all the tops, green leaves and trash left on the field.

Discussion

The mean ratio of weight of stems reaped to ultimate trash left in the field is almost exactly 4 to 1, which is numerically the same as the ratio derived from Ross's original data recorded by Stubbs. Considerable variation in the value for this ratio was found for plant-cane as contrasted with ratoons, and for the different varieties in the same stages of growth. There is a tendency for the ratio to be highest in plant-canes. The values are too irregular, however, for generalising. Judging by the magnitude of the yields of stems, the growth conditions under which the crops were produced were fairly good.

In the previous article (1), the contribution to soil organic matter made by sugar-cane residues was discussed. It was calculated that a 40-ton per acre crop of cane-stalks would produce 10 tons of leafy material, expressed as dry trash, and that this amount of cane-trash would produce about 21½ cwt. of soil humus per acre which is more than twice as much as that contributed by the quantity of root residues

TABLE I

RELATIVE PRODUCTION OF SUGAR-CANE STEMS AND TRASH

(College Farm, 1946)

Variety	Stage	Actual yields			Total leaves as trash *	Percentages of total crop		Ratio
		Stems	Leaves and tops	Dry trash		Stems	Trash	stems / trash
		tons per acre			t.-a.			
B 37161 ...	Plants	54.2	11.6	10.2	14.5	78.9	21.1	3.74
B 34104 ...	,, ...	48.5	4.9	6.5	8.3	85.4	14.6	5.85
B 3439 ...	,, ...	48.4	6.5	7.5	9.9	83.0	17.0	4.88
BH 10/12 ...	1st rats.	35.0	2.6	7.1	8.1	81.2	18.8	4.32
POJ 2878 ...	,, ...	23.6	1.9	6.2	6.9	77.4	22.6	3.42
B 3013 ...	,, ...	28.1	3.2	5.7	6.9	80.3	19.7	4.08
B 34104 ...	2nd rats	33.5	4.0	9.0	10.5	76.1	23.9	3.18
B 3439 ...	,, ...	23.0	4.4	4.7	6.3	78.5	21.5	3.65
					Average	80.1	19.9	4.14

*Calculated from determined moisture contents of samples of green leaves tops and trash.

left in one acre 6-inches of soil by an average cane crop. The trash production figures used in the previous article were based, as above, on Ross's data, quoted by Stubbs, and these are now corroborated by direct measurements made in the field.

Conclusion

Values abstracted from published data, together with experimental results recently obtained at the College Farm in Trinidad, show that, for the sugar-cane crop, the ratio of stems to trash ultimately left on the land after the tops have been removed and the leaves stripped off, is approximately 4 to 1. Thus a 40-ton per acre crop will be accompanied by about 10 tons of trash derived from tops and leaves left on the land to dry.

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(1) The Contribution made by Sugar-cane Roots to Soil Organic Matter. F. Hardy, *Trop. Agri.* Trin., 1944, pp. 203-209.

(2) Some Further Information on Humus. H. M. Leake, *International Sugar Journal*, 1938, 50, p. 6.

(3) Sugar-Cane, Vol. I : Stubbs, 1897, *Louisiana Sugar Expt. Station*, New Orleans, pp. 208. *See* p. 32.

SOIL DEPLETION PLOTS.

An experiment was begun in Louisiana to see how rapidly an initially rich soil could be impoverished by poor management. The field selected was on an alluvial soil that had been in sod for many years until 1923, when it was ploughed and planted with corn and soy beans every year until 1929, each corn or soy beans crop being ploughed under in the fall. By that time the soil was rich in organic matter and in a high state of fertility. It was then planted in cane (3 varieties). Each plot went through three cycles of plant and stubble crops. The crops were cultivated as usual, but no summer or winter legumes were turned under; no fertilizer of any kind was used on the plant crop, and each of the stubble crops received only 36 pounds of mineral nitrogen per acre. The soil thus received no organic matter except from the cane trash and roots, and a small amount of weed growth in the summer.

At the end of the third cycle (13 crops in all), the average yield of cane from the first stubble crops had fallen from 3946 to an average of 2930 tons per acre; the second stubble crops from 3114 to 2482 tons. It is evident that omission of a regular crop rotation with summer and winter legumes is a good way to deplete a fertile Louisiana cane soil.—(*Sugar*, 42, 53, 1947).

THE RELATIVE YIELDS OF BANANAS AND POTATOES

By

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Introduction

It has been widely assumed and commonly stated that bananas and plantains are capable of producing much larger yields of food per acre per year than are temperate crops, in particular potatoes. Thus Kingsley (1889) says: "The plantain alone ought, according to Humboldt, to give one hundred and thirty-three times as much food as the same space of ground sown with wheat, and forty-four times as much as if it grew potatoes". Willis (1897) states: "The plantain or pisang.... is everywhere cultivated in the tropics, yielding 40 times as much food per acre as even the potato" but this statement is modified in later editions of the same work (e.g. 1925) to: "yielding much more food per acre than even the potato". Fawcett (1913, p. 6) states that the banana yields 242000 lbs. (108 tons) of food per acre, the potato only 4000 lbs. (1.8 tons), the ratio of the two yields being about 60 : 1. Such statements as these are so evidently erroneous that it is thought worthwhile to examine such data as are available in order to determine what, if any, is the difference between the banana and the potato in respect of yearly food production per acre.

The Yields of Bananas and Potatoes

(a) *Bananas.* Adequate data on yields are available only for two bananas, namely the Gros Michel or Jamaica banana and the Cavendish, Chinese or Canary banana. They are not available for any plantain, so far as the writer is aware, but both the bananas in question have large bunches when properly grown and it is thought that differences between them and varieties of plantain can not be very great, especially when probable compensation by rate of production of bunches and rate of maturity are taken into account.

According to Reynolds (1927) an average yield of Gros Michel in Central America is about 125-150 count bunches per acre per year. The mean weight of bunches imported into the U.S.A. in 1943-5 from Guatemala, Honduras, Costa Rica and Panama was about 60 lbs. (Anon., 1945), indicating an acre yield of 3.8 tons per year, say 4 tons. Similarly, the data of Fawcett (1913) and Popenoe (1941) indicate that 300 bunches per acre per year is very good (even exceptionally good in Central America) and this, at 60 lbs. per bunch, corresponds with an acre yield of 8.0 tons. There are no data on maximal yields but Fawcett mentions an exceptional figure of 500 bunches per acre and an exceptional average weight may be taken as 75 lbs. 600 80-lb bunches may then be taken as a rough estimate of what may be expected as a maximal yield, say 21 tons.

The Canary banana is grown, according to Holmes (1929), under conditions approximating to sand culture, with irrigation, some farmyard manure and full artificials. Yields are correspondingly high despite relatively slow growth of the suckers. Production in Grand Canary in 1928 was 82704000 kg from 1723 hectares, indicating an average of 19.1 tons per acre (Holmes, 1929, Appendix II). The average number of bunches produced per acre per year is 500-780, each having a weight of 55-86 lbs on the basis of the acre yields of 19.1 tons cited above. This weight is rather higher than that quoted elsewhere in the same work, namely 20-30 kg (44-66 lbs). On the basis of 640 bunches per acre, each weighing 25 kg (55 lbs), yields would be about 15.7 tons per acre per year. Thus the average may be taken as 16 tons, approaching 20 in a good season. Maximal yields may be guessed very roughly to be about 36 tons (1000 80-lb bunches per acre). Holmes mentions in passing a record bunch which weighed 60 kg (132 lbs) and which might have attained 65 kg had it not been cut prematurely to avoid loss.

(b) *Potatoes.* The yield of potatoes is notoriously variable from year to year but is said by Watson and More (1933) to lie between 6 and 7 tons on the average in Britain, with 16 tons as an exceptional figure. The average in the U.S.A. in 1934-5 was 3.0 tons (U.S. Dep. Agric., 1936), the broad difference between the two countries lying parallel with that noted by Hutcheson and Wolfe (1924) for the period 1910-19 (5.8 and 2.6 tons respectively). The British average may be taken as 6 and the American as 3 for comparative purposes. The maximum recorded yield of potatoes is 31.0 tons per acre (in the U.S.A., Willcox, 1937).

Comparisons

The figures given above refer to gross yield of produce, whether of fruits or tubers, not to edible material alone. About 5-7% of the weight of a bunch of bananas is stalk, while skin contributes some 35-40% of the weight of the fruits (Reynolds, 1927; Wardlaw, Leonard & Barnell, 1939); the edible portion therefore constitutes only about 59% of the weight of the bunch. A further complication is introduced by the fact that the figures for the weights of bunches of Gros Michel were obtained from bunches exported from Central America to North American markets. Such bunches are always harvested in what is known as the "heavy 3/4 full" condition in which the fruits will withstand without ripening the necessary period of refrigerated storage. If left for a further period and then reaped in a condition suitable for local consumption without storage, the weight of fresh pulp per fruit increases from 90 to 120 grams, an increase of about 33% (Wardlaw, Leonard & Barnell, 1939). These results apply to Gros Michel and, in the absence of direct information on the point, are used here also for the Canary banana.

Virtually the whole of the potato is edible but doubtless acre yields include a certain amount of dirt and a small amount is lost in peeling; 5% will probably cover this.

The edible portions of both banana and potato contain about 25% dry matter, very largely carbohydrate (Reynolds, 1927; Barnell, 1940) so that no correction is needed on this score.

Results are summarised in Table 1. Potatoes in Britain yield an amount of food intermediate between that yielded by bananas in Central America and the Canaries. The American potato average lies rather close to the Central American banana average but is considerably less than that obtained in the Canaries. The maximal recorded yield of potatoes is of the same order of size as the maxima for bananas and it seems improbable that the estimates of maximal banana yields can be so far wrong that a correction could reveal any great difference. However, too much weight may obviously not be placed on this comparison in view of the admittedly arbitrary method of estimation of maximal banana yields.

Discussion

However great the uncertainty which attaches to the details of the calculations made above, it seems certain that there is little difference in the amounts of food yielded per acre per year by bananas and potatoes under their respective agricultural conditions. And no plausible modification of the assumptions made and the figures used can seriously alter the comparison. The various statements quoted at the beginning of this note are therefore wrong, and even the undoubted increase in potato yields since the early 19th century when Humboldt made the statement cited by Kingsley, can do little towards reducing the discrepancy. These statements are based, it may be surmised, on calculation from the weight of an exceptionally fine bunch extrapolated to acre yields by means of hypotheses as to bunch production, planting distance, etc., a procedure which is virtually certain to give erroneous results. They are associated, as might be expected, with the complex of widely-held misconceptions relating to the "inexhaustible fertility of tropical soils".

The pawpaw (*Carica papaya*), it is interesting to note, yields up to 48 tons of fresh fruit per acre per annum in Trinidad (Phillis, personal communication). 70.3% of the fruit at or just before ripeness is edible, the remainder consisting of skin, seeds and the placental pulp in which the seeds are embedded; 12.1% of the edible portion is left after oven-drying for 48 hrs. at 100° C. (unpublished data, based on averages for six fruits). An exceptional yield of edible dry matter from the pawpaw in Trinidad would then be 4.1 tons per acre per annum; and this, again, is of the same order of size as the yields of bananas and potatoes (see Table 1, taking dry matter as 25% of fresh edible material).

Heath and Gregory (1938) made a survey of the data available on net assimilation rates of a range of tropical and temperate crop plants. They found that the rates were sensibly constant at a level of rather less than one gram per square decimeter of leaf surface per week and concluded that there must exist some compensation (of unknown nature) for the effects of different day-length and light-intensity. In this connexion, it is worth noting that, although there are no data on net assimilation rates, the comparisons made above show that the potato, with a short growing season under long-day conditions, yields about the same amount of edible matter as the banana

TABLE I

YIELDS OF BANANAS AND POTATOES

Crop	Place		Yield (tons per acre per year) Gross	Edible matter: For export	Edible matter: For local use
Gros Michel Banana	Central America	Average	4	2.4	3.2
		"Good"	8	4.7	6.3
		Maximal*	21	12.4	16.5
Canary Banana	Canary Islands	Average	16	9.5	12.6
		"Good"	19	11.2	14.9
		Maximal*	36	21.2	28.2
Potato	Britain	Average	6	5.7	
		"Exceptional"	16	15.2	
Potato	U. S. A.	Average	3	2.9	
		Maximal	31	29.5	

*Estimated

with a long growing season under short-day conditions. Actually, the banana receives a rather greater total number of hours of daylight than the potato, as follows :

Crop	Growing season (Months)	Daylight per day (Hours, approximate)	Total daylight (Hours)
Banana	12	12	4400
Potato	6-7	15	2900

Summary

A review of the published data on yields of bananas and potatoes shows that they are of the same order of magnitude, the basis of comparison being amount of edible matter produced per acre per year.

The writer wishes to thank Dr. E. Phillis for helpful criticism and for information on the yield of pawpaws in Trinidad.

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THE MOON AND PLANT GROWTH*

Beliefs that the phases of the moon have a differential effect on the rate of development of plants are both ancient and world wide. Proof by rational experiment seems to have been sought more than two hundred and fifty years ago by La Quintinye, the horticulturist, and some years later by Duhamel du Monceau 1, the forester. Neither obtained any positive evidence of lunar influence. Since then, scientific interest in the subject has been revived intermittently, either by the 're-discovery' of lunar rites in the agriculture of civilised countries, or by the impact on Europeans of the impressive faith of primitive peoples, particularly in the tropics and sub-tropics.

The literature on the moon and plants can be assigned to two groups: one comprising reiterations of peasants beliefs, myths and rule, both ancient and modern, and similar unsubstantiated statements; the other comprising experiments supported by numerical data capable of statistical analysis. This second group consists of (a) experiments mainly of the anthroposophical school, which demonstrate the existence of lunar effects on the growth of plants; and (b) experiments of professional horticulturists and foresters, which prove that there are no such effects, or that, if they do exist, they have no value in agricultural practice.

The beliefs which dominate primitive rural economy and the emphatic reports of credulous observers are very numerous, but they provide no significant evidence. Only experimental data need be considered; they may be briefly summarized as follows :

(a) *Kolisko's work*. According to the investigations of L. Kolisko in Stuttgart during 1926-35, the particular phase of the moon at the time of sowing does influence the period and the percentage of germination, as also the subsequent growth of the plant. The most favourable date to sow is two days before the full moon for leaf-and-fruit-bearing garden crops (such as cabbages, peas, tomatoes), for root-crops (such as radishes, beetroots, carrots), for flowering garden annuals, and for wheat, maize, etc. In general, these plants show better germination, more vigorous growth, and greater yields than those sown just before the new moon. Kolisko affirms that the lunar influence is not fully effective unless there is rain or artificial watering during the germination period, but the stimulus once acquired remains decisive throughout the periods of growth, flowering and fruiting. As regards growth during a lunar phase, she found that on the whole the response of wheat is greater during the waxing than the waning phase.

In later experiments to determine the depth to which the action of the moon penetrates the soil, Kolisko found that at a depth of 1 metre the effect

* Article by C. F. Beeson, reproduced from *Nature*, 158, 572-573.

on wheat is nearly identical with that at the surface; at 2-3 metres the maximum growth is generally reached in a full-moon period; between 5 metres and 16 metres the influence is weaker but is still shown by greater growth at the time of the Easter full moon. She considers that each year has a certain dominating lunar period, and that the Easter full moon has a special significance for the whole year. E. and L. Kolisko's recent book, 'Agriculture of To-morrow,' reviews cosmic influences on plant growth.

(b) *Other investigators' work. Germination.* Experiments on the germination of garden crops have been done by Becker (1937—38)3, Bergdolt and Spanner (1937—39)4 at Munich; by Mather and Newall (1940—42) 5, 6 at the John Innes Horticultural Institution; similar experiments with spruce seed were done by Rohmeder (1935—37) 7 at Munich. All these investigators agree that no consistent effect of the moon is observable and that all chance variations possibly assignable to any one of the moon's quarters are evened out with an adequate number of repetitions. At meetings of the Societe nationale d'horticulture de France in 1924, several horticulturists testified to the absence of lunar effects on sowings and seedling growth; earlier work of Arago, Flammarion and others in France between 1859 and 1909 was cited in confirmation8.

Reproduction. Periodicity in the production of sexual cells of the marine alga, *Dictyota dichotoma,* has been demonstrated by Williams (1905) 9, Hoyt (1907) 10 and Lewis (1910) 11, but the period is fortnightly on the coast of Wales and Naples, and four-weekly in New Carolina, and the phase dates differ.

Paralized light. Semmens (1923) 12 showed that moonlight is plane-polarised and increases hydrolysis of starch with diastaste. Esenbeck and Suessinguth (1930) 13 and Macht (1926) 14 showed that polarized light of low intensity may produce a very slight increase in growth in length of plants. Wright (1927) 15 found the highest degree of polarization of moonlight at the ends of the first and third quarters. The anthroposophists consider that the moon's influence works in darkness and below ground.

Felling dates and seasoning of timber. Moisture-content is the most important physical condition influencing the rate of decay of wood. The amount of water in the wood of a living tree is known from many careful determinations to differ with the species of tree, and for some species to vary seasonally, for others to be fairly constant throughout the year. No variation related to lunar phases is known for any tree, but Beeson and Bhatia (1936) 16 found a regular lunar rhythm of sap increasing from the full to the new moon and decreasing from the new to the full moon in *Dendrocalamus strictus* in India. Knuchel and Gaumann's (1930) 17 work with spruce and silver fir in Switzerland based on a sequence of fellings in the same phase of the moon is typical of the exact knowledge now available. The season of felling is proved to have no substantial influence on specific gravity, moisture-content, shrinkage, resin-content or working qualities, but it strongly influences the rate of seasoning. The effect of the season of felling on the rate of drying, and the effect of weather on the activity of decay organisms dominates any effect that may be due to the phase of the moon.

Borer damage. Numerous entomological records show that the liability of felled trees to attack (that is, oviposition) by borers depends on one hand on the dates of the emergence period and longevity of the adult insect, and on the other hand on the progress of drying out of bark and sapwood, or the amount of depletion of starch. The two latter factors can be controlled in many species of trees by logging procedure which entirely ignores lunar dates. Beeson and Bhatia (1936) and Gardner (1945) 18 have proved that the intensity of *Dinoderus* damage to bamboos in India depends on the amount of starch present in the felled culm; the starch-content of the living culm varies seasonally, not according to the lunar phase, and no advantage is obtained by felling in relation to the phase date.

Lunar periodicity exists in some animals, but they are marine or aquatic species (Fox, 1924 19 : Hora, 1929 20).

Yield of resin, latex, etc. Variations in the yield of resin, latex, maple syrup, gums and tannin are explicable in terms of tapping systems, genetic factors, weather and environmental conditions ; experience is very considerable, but in no case has any advantage attributable to the moon been discovered. For example, Ferrand's work (1941) 21 on *Hevea brasiliensis* in the Belgian Congo revealed that the daily concentration of latex varies with weather conditions, and the local concentration in the same tree depends on the exposure to sunlight of the crown directly above the tapping-point. Changes in the gutta-content of the root of *Euonymus verrucosus* in the U.S.S.R. follow the seasonal development of the plant, and the resin-content varies in inverse proportion (Yurkevich, 1944) 22. The maximum tannin-content of seeds of *Terminalia chebula* is found in seeds collected in January anywhere in India; this period is also that of optimal germinative capacity (Prasad, 1946) 23.

Summary. The only experimental evidence for the existence of lunar influence on the growth of land plants is that published by L Kolisko. All other investigators in many parts of the world have been unable to discover any consistent correlation between the moon and the vital processes of land plants ; some admit that if a lunar effect does exist it is so obscure as to have no value in agricultural practice.

A more detailed review of the subject will shortly be published by the Imperial Forestry Bureau, Oxford.

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CHEMICAL NOTES

(Compiled by the College Department of Chemistry and Soil Science)

Ion Exchange Process for extracting Cinchona Alkaloids

A cyclic system for the extraction of alkaloids from crude drugs by means of ion exchange has been devised. Alkaloids of cinchona were extracted by dilute acid and recovered by ion exchange with an over-all average yield of 81.2% within an average period of 82 hours. Dried bark from ordinary commercial sources was used. Even greater efficiency may be anticipated when undried bark is utilized. This system thus permits the use of either dry or undried raw material. The process lends itself equally well to either small or large scale operations. The use of portable equipment makes possible the exploitation of formerly inaccessible cinchona stands by drastically reducing the haulage requirements. The economy and simplicity of this method of extraction would seem to forecast its wide application to industrial alkaloid recovery.

(*Indus. Eng. Chem.* 38, 576, 1946).

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Effect of Fertilizers on Production of Alkaloid by Plants

The quantity of alkaloid produced is to some extent under control through cultural methods, especially the appropriate use of fertilizers. Alkaloids are formed "in competition" with other demands upon the nitrogen and carbohydrate stocks of the plant. There is an evident tendency to the establishment of limit values, and perhaps of variable, though not simple, equilibria between alkaloids and other nitrogen sinks, such as the proteins. The simplest and most reliable method of increasing the yield of alkaloid is to arrange for good vegetative growth of the plant. This implies a porous and calcareous soil, optimal spacing (about 30 in. x 30 in. for belladonna) and good general fertilization with perhaps an excess of nitrogen and lime. Under such conditions the yield of alkaloid increases *pari passu* with the general increase of plant material. To increase the percentage alkaloid, that is, to divert nitrogen and carbon from other metabolic paths into the alkaloid one, is a more difficult and less certain undertaking. The only method at present holding out a prospect of success is unbalanced nitrogen manuring. Attempts in Great Britain, both on the scale of pot cultures and field plots, have shown significant but rather small increases of alkaloid per cent. dry weight. A rather interesting feature is that additions of ammonium sulphate, so heavy as to stunt root growth, have caused increases in the percentage of alkaloids present. On other soils no increase has been recorded; the critical difference seeming to be deficiency of lime and absence of clay. The belief that liming in itself tends to raise the alkaloid percentage lacks experimental confirmation at present. A still more elusive, but highly interesting problem lies in the effect of the other major mineral nutrients, potassium and phosphorus. Results repeatedly show slight reduction of alkaloid percentage due to potassium, and slight increase due to phosphorus, particularly in the roots. The effect generally fails to reach a probability-level of 0.02 (19 to 1 odds) in any one experiment, but the summation difference between lack of potassium and lack of phosphorous may be highly significant. In view of the well-known effect of potassium in promoting protein synthesis, the apparent retardation of alkaloid formation affords an interesting suggestion of competition between the two processes for available nitrogen. The alkaloid is nevertheless a very unsuccessful competitor. In young belladonna leaves about 95 per cent. of the total nitrogen is in the proteins and 0.3-0.9 per cent. in the alkaloids. (Abstracted from *Nature*, 158, 654-656, 1946.)

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Du Pont Weed Killer

Remarkable results are being claimed for 2, 4—D ("Karmex"), the active ingredient of which is the ammonium salt of 2, 4 dichlorophenoxyacetic acid. It has already been in use as a plant hormone to stimulate the rooting of cuttings in the propagation of trees and shrubs, and to increase the "set" of fruit in orchards. It is specific against most types of common weeds and is stated to have no effect on grass. Its manner of action is not understood, but it is generally thought that 2, 4—D destroys weeds by forcing them to deplete their food reserves, thus affecting in some way the starch content of the plants. Within the first week after application, indications of the killing action usually show up as bending, twisting and splitting of the stems. This is followed by yellowing of the foliage and eventual death and decomposition of the weeds, roots and all. The time required for killing different weeds varies from 1 to 4 weeks. (*Int. Sug. Jr.*, 48, p. 335, 1946.)